After Action Review in Simulation-Based Training

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The after action review (AAR) is a mechanism for providing feedback to organizations on their performance of collective tasks. It is an active process that requires unit members to participate in order to benefit. The AAR is a method of providing feedback to units after operational missions or collective training exercises [23]. The AAR is an interactive discussion, guided by a facilitator or trainer known as an AAR leader. During the AAR, unit members discuss what happened, why it happened, and how to improve or sustain performance in similar situations in the future.

1.0 SIMULATION-BASED TRAINING ENVIRONMENTS

Military Training is always a simulation whether it occurs at a sophisticated instrumented range, in a collective training simulator system, or in a command and staff exercise driven by a math model driven war game. Training occurs in live, virtual, constructive, or mixed simulations of battlefield environments. There are always compromises in training with how tasks would be performed in combat. In the live environment, units use operational equipment and actual terrain and perform against an opposition force composed of military personnel (live force-on-force) or targets (live fire), depending upon whether the unit is employing simulated weapons' effects or firing live rounds. In virtual environments, units use simulators to represent equipment and weapons. Weapons effects, terrain and enemy forces are computer generated. In constructive environments, battlefield outcomes (e.g., the unit lost thirty percent of its personnel) are determined by sophisticated math models in order to provide battle effects supporting command and staff training. Mixed environments include elements of two or more of the simulation environments. Training in all of these simulation environments should provide individuals and units with feedback about how their actions contributed to mission success or failure, casualties received, and casualties inflicted on the enemy, the bottom lines of collective performance.

Live simulation training is widely available, in the form of ranges and maneuver areas. The most highly supported form of live simulation training is generally found at ranges that support engagement simulation and vehicle or aviation asset tracking. Examples of these ranges are the US Army's National Training Center or the US Navy's Top Gun program. They differ from local area ranges in that they provide a cadre of observer/controller/trainers, a dedicated opposing force, instrumentation that is capable of collecting position location, firing and status data, and teams of analysts supporting observer/controller/trainers from a data collection and analysis facility.

Virtual Simulation training systems vary widely across services and nations. Virtual training environments can range from driver and gunnery trainers to sophisticated networks of simulators representing aviation assets operating in a coalition format. The introduction of game-based training has expanded the scope of virtual training and made it more widely available because of the games relatively low cost.

Constructive Simulations fall into two categories. Math model based attrition models represent the actions of military units and serve primarily as drivers for training exercises of command groups and staffs.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 JUL 2007**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **After Action Review in Simulation-Based Training**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Research Institute for the Behavioral and Social Sciences Orlando, Florida USA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002028.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**12**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The constructive simulation provides the inputs to commanders and staff's decision making processes. A second more recent form of constructive simulation is more entity and rule-based. These simulations provide semi-automated forces to be enemy and adjacent friendly forces for virtual simulations. The Close Combat Tactical Trainer (CCTT), a U.S. Army heavy forces virtual trainer, utilizes CCTT SAF to generate enemy forces for the training audience to fight.

2.0 INTRINSIC FEEDBACK

Intrinsic feedback cues and guides unit behavior during task performance [4], whether the task is being performed in an operational or training context.. For example, an infantry unit may call in artillery fire on a target and receive intrinsic feedback when it observes that simulated or actual rounds impact too far from the intended target. Someone from the unit assigned to observe the effects of the artillery fires would then provide the supporting artillery unit with guidance for adjusting their fires. A portion of intrinsic feedback comes from simulations or actual weapons effects (the location of artillery impact) and part comes from unit actions (an observer providing the artillery unit with directions for adjusting fires).

As a rule of thumb, there are more gaps in intrinsic feedback for a unit that is not well trained, because unit members are not providing their portion of the feedback. Continuing with the artillery example, not having an observer in position can result in a gap in terms of a unit's knowledge of the effectiveness of its artillery. From a broader perspective, if there are failures to communicate information up and down the chain-of-command during an exercise , then there will be gaps in feedback needed to cue and guide performance. If unit members are not sure about what aspects of the tactical situations they should be monitoring, then additional gaps in feedback are to be expected.

An important difference between individual and collective performance is that in collective performance much of the information needed to cue and guide performance comes from other people. To be fully trained unit members must learn how to provide this information (i.e., their part of the intrinsic feedback). Improved capability to provide intrinsic feedback at the right time to the right people is evidence that unit performance is improving.

3.0 EXTRINSIC FEEDBACK

For a unit to improve its performance unit members will in most cases need more feedback about what happened during an exercise than that gained by participating in it and observing what happened. Because of the so called "fog of war", when an exercise is over, participants sometimes have a limited perspective regarding what happened, based upon the information available to them and what they saw, heard and smelled. This limited perspective is referred to as perceived truth. Ground truth is the term used to describe the actual events that occurred. Less trained units are expected to demonstrate a greater disparity between perceived and ground truth, simply because much of the intrinsic information that was available was not either perceived or used. Events may be happening quickly and open to differing interpretations. Perceptions and memories of the occurrence, sequence, and timing of events can be greatly distorted leading to generation of causal relationships which are not based on the actual facts [8].

Extrinsic feedback is provided by an outside source, usually observer/controllers or trainers after an exercise ends. It is designed to help participants understand the ground truth situation relative to their perception of perceived truth and to investigate what caused the events to occur as they did. Extrinsic feedback consists of information that the exercise participants don't ordinarily have available to them. It can provide insights into how to improve or sustain performance in the future.

A simulation is effective to the extent that exercise participants can appropriately recognize intrinsic feedback regarding their performance, and extrinsic is provided to clarify misperceptions. Extrinsic feedback, by providing information on exercise outcomes, allows the actions of individuals to be linked to higher level exercise outcomes. Sometimes exercise participants recognize the impacts of their actions via intrinsic feedback, but at other times they are not aware of these impacts until they receive extrinsic feedback.

4.0 EXTRINSIC FEEDBACK METHODS FOR COLLECTIVE TRAINING

Formal post-exercise feedback sessions are one of the types of extrinsic feedback that can be used to improve unit performance [4]. The After Action Review (AAR) is a method of providing extrinsic feedback to units after operational missions or collective training exercises [23]. Simply put, the AAR is the controlled sharing of intrinsic feedback combined with group problem solving. Exercise participants play differing roles and are located at differing points within the battlespace, so each participant receives relatively unique intrinsic feedback. Extrinsic feedback can be used to correct misperceptions and clarify events and effects. The AAR process may provide unit members with a view of collective (team, unit, or organizational) performance that was not apparent to, or viewable by, any one participant during an exercise [14], including trainers who were observing the exercise. The AAR uses a Socratic Method in which a series of leading and open-ended questions are used by an AAR leader to help those in the training audience discover what happened and why.

A debrief or critique conducted by one or more observers of a training exercise is an alternative to the AAR [19, 9] and is a more traditional way of providing feedback by trainers. The person or persons who provide the critique become the source of ground truth as they see it. Their role is to interpret events as they saw them and describe to the training participants what they think happened, why they think it happened, and what they think the unit should do about it. Critiques are an extrinsic source of feedback. A major difference between the AAR and critique is that the critique provides the training participants with conclusions reached by the person giving the critique rather than facilitating the training participants to reach their own conclusions. Critiques can easily be taken as criticism since the opinions expressed are based on perceptions, judgments and possibly misinterpretations of ground truth. Further, the critique is unable to make use of diagnostic information that may be known only to exercise participants.

The AAR leader functions as a discussion facilitator. Training participants are expected to examine their performance through guided self evaluation. They are encouraged to identify their problems and develop approaches to correct them. It is assumed that use of the AAR feedback method results in units claiming ownership of the diagnosis of problems and the corrective actions they identify [19].

Extrinsic feedback regarding unit performance focuses on conceptual knowledge rather than procedural knowledge. Feedback is likely to be more explanatory than directive in nature. The whole process of using interactive discussions to decide what happened, why it happened, and how to improve or sustain performance engenders explanations. Explanatory feedback is superior to directive feedback in terms of conceptual knowledge acquisition [16].

Post-exercise feedback, by definition, is delayed rather than immediate. It could, conceivably be used in conjunction with immediate feedback in the course of an exercise (i.e., through coaching, mentoring, intelligent tutoring, and/or the application of during action review aids) so that a unit can take immediate corrective action and perhaps accelerate the training process [11]. In the case of collective training, corrective actions in mid exercise may help prevent a unit or team from creating a tactical situation that detracts from the intended training objectives of the exercise.

5.0 HOW REALISTIC BATTLEFIELD SIMULATIONS SET THE STAGE FOR AN AAR

The AAR was based upon the “interview after combat” used in World War II by military historian Samuel Lyman Atwood (S.L.A.) Marshall and others to find out what happened during missions [3]. The process was adapted for training events as the capability to provide realistic simulation of weapons effects occurred during the 1970s and 80s [3, 17]. Prior to development of engagement simulation technologies in the 1970s most military collective training exercises casualty exchanges and mission outcomes were based upon the subjective judgments of umpires. Such judgments were insufficient to prepare participants for an “interview after combat,” because the participants didn’t believe that their status as casualties necessarily resulted from their behavior. The development of tactical engagement simulation technologies provided a means for objective casualty determination [22]. Perhaps the best known example of TES is the use of lasers and laser detectors to simulate the effects of line-of-sight weapons, such as rifles and tank main guns. The later development of virtual simulations such as Simulation Networking (SIMNET) and The Close Combat Tactical Trainer (CCTT) eliminated many of the inaccuracies of live TES casualty assessment and were capable of more fully representing ground truth [7].

6.0 THE ROLES OF AAR AIDS IN SUPPORTING FEEDBACK

To be effective, AAR discussions need to be guided by an AAR leader. The leader needs one or more start points for the discussion and at least a general idea of where the discussion will head. The job of the AAR leader is made easier to the extent that they are already aware of the types of problems the unit has been experiencing. If all an AAR leader knows about a mission is that a unit sustained heavy casualties, the Socratic Method will take a long time to identify the root causes of the problem. If the AAR leader and the unit know that most of the casualties occurred within a few minutes of making contact with the enemy and that few friendly vehicles returned fire upon contact, they are closer to identifying and understanding what happened and why. The AAR does not require an exhaustive review of all aspects of a unit’s performance. Instead, trainers are expected to focus on aspects of performance closely linked to key exercise events and outcomes.

At instrumented ranges and in virtual simulations AAR aids prepared from electronic data streams can document or illustrate aspects of performance that are close to root causes of weaknesses and strengths. Developments in battlefield simulations technology have provided trainers with a record of electronic data describing position location, firing events and communications over the course of an exercise. AAR software systems have been developed that allow this data to be converted into a variety of AAR aids describing or illustrating ground truth [14]. For example, a graph showing the number of rounds fired by each vehicle in a platoon over time may make the point that only one of the vehicles in the platoon fire was involved in the early portion of an engagement. To gain this information from the AAR process, a unit would have to slowly reconstruct the sequence of events based on their memories. AAR aids also offer the benefit of providing units with demonstrable ground truth when their recollections are at odds with what actually happened.

To the extent that AAR aids illustrate root causes of exercise events, rather than outcomes, they expedite the AAR process. AAR aid generation capabilities that examine exercise data streams to check specific aspects of performance offer a means of helping AAR leaders and units diagnose strengths and weaknesses.

The most frequently used AAR aid is a sequential replay of exercise events. A replay, however, is not necessarily the most efficient or effective way of illustrating key aspects of performance. Sometimes AAR

aids that summarize activity over a period of time can be more effective. A graphic tracing the movement of a unit may be able to quickly illustrate that a unit backtracked, indicating that the route reconnaissance may have been inadequate.

Efforts to develop innovative AAR aids have not always been successful [21]. Efficient aids should provide information that would otherwise have to be gleaned from lengthy reviews of replays. However, poorly conceived aids tend to confuse rather than clarify the situation because they do not present information in a manner that is intuitive or clear to the training participants. The ideal situation would be one in which training participants have learned over time to expect certain AAR aids to be presented after an exercise and they know what information is to be gained from each type of aid. It has been difficult to reach this goal because each training/simulation environment has different capabilities to support AAR aid production. Live simulations are limited by the quality of the data generated by the instrumentation and engagement simulation systems. Constructive simulation often will not represent entity level performance, but rather aggregate performance of units. As mentioned above, virtual simulations represent the best opportunity to provide accurate and appropriate AAR aids because most of the data of interest can be easily collected from a network.

AAR aids provide units with an improved perspective regarding what actually happened during an exercise that more accurately reflects ground truth.. An important goal of the unit is to identify corrective actions it can take that will provide unit members with an improved perspective as it is conducting training and operations in the future (i.e., better intrinsic feedback to cue and guide unit behavior).

7.0 A RECENTLY DEVELOPED AAR TOOL FOR VIRTUAL ENVIRONMENTS

In live and constructive collective training, the AAR is a crucial component of the training process. The same is true of virtual simulation based training. The first collective training virtual simulation, SIMNET, was developed by DARPA, to provide training and better understand the technical requirements of networked simulators. SIMNET was initially developed without an AAR system, a capability to produce AAR aids from recorded movement, communication and firing data. AARs were dependent on the perceptions of the training participants. In the early 1990s the US Army Research Institute with contracting support from Perceptronics and the Institute for Simulation and Training developed the Unit Performance Assessment System [13] to capture SIMNET exercise data and provide AAR aids to support the AAR process. Later the Automated Training Analysis and Feedback System [4] was developed also for the SIMNET system. These AAR systems addressed technical issues of extracting information from the simulation data streams, reducing operator workload, and producing aids and displays that went far beyond a simple replay of the exercise.

In the 1999 – 2002 timeframe, as part of an overall project to develop capabilities for simulation-based training of dismounted combatants, an AAR system was developed called the Dismounted Infantry Virtual AAR System (DIVAARS). The goal was to develop an AAR system that incorporated lessons learned from earlier AAR systems and was tailored to the unique requirements of small unit dismounted.

Infantry training in a virtual environment. An emphasis was placed on being able to meet the special challenges of urban environments on military operations and training. The challenges are primarily visual in that "buildings and other structures break up the visual field and limit the portion of the battlefield that can be observed by any one person." [12, p. 59]. This required an AAR system that could not just replay an exercise, but could in addition support the AAR goals of presenting exercise events and data in a manner that would facilitate trainee understanding of what happened, why it happened, and how to improve.

For determining "what" happened during a mission, the DIVAARS recreates exactly what happened during the mission. During the replay the unit members can observe the location, posture, and actions of all the other members. And, unlike live field training, DIVAARS can replay mission action exactly as viewed by any of the participants. These features not only support the trainees' explanation of why events happened, but also help the unit members develop shared mental models of individual and unit tasks. Watching the replay may also strengthen group identification and cohesiveness. Finally, several DIVAARS features (such as depicting critical events in slow motion and from multiple perspectives) enhance memory so those lessons learned are more likely to be employed in subsequent training and missions.

Figure 8-1 shows a sample DIVAARS display with many of these features that can be utilized in supporting an AAR.

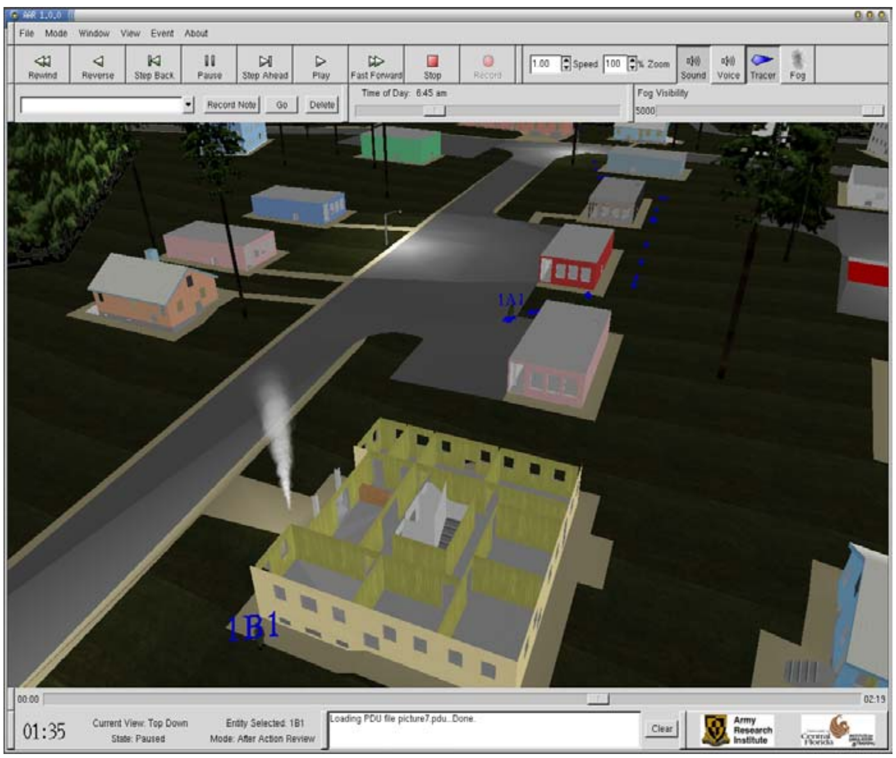

Figure 8-1: DIVAARS Display.

These features are summarized below.

Playback. A linear beginning-to-end playback is unlikely to the most efficient way to provide the trainees with an understanding of what happened during an exercise. The replay system includes actions such as pause, stop, record, play, step forward, fast-forward, rewind, fast-reverse, and step-reverse. Variable playback speeds are available. Furthermore, the AAR Leader has the capability to mark events during the exercise and jump directly to them during the AAR.

Viewing Modes. Viewing scenario events from different perspectives is essential to understanding what happened. Multiple viewing modes are available to the AAR Leader during both the exercise and the AAR. Many preset views can be selected at any time prior to or during the exercise for immediate use. These can be

used for perspectives or positions that the AAR Leader thinks will be useful, such as the view from an enemy position. The variety of viewing modes provides added capabilities during the AAR process.

- Top-Down – A view of the database looking straight down from above. It can be moved left, right, up, down, and zoomed in or out. The AAR Leader can also lock the view onto an entity, in which case it will stay centered directly above that entity as it moves through the database.
- 2D View – This is the traditional plan view display. It is the same as Top-Down except that depth perspective is not shown.
- Entity View – By selecting any entity, (including enemy or civilian), the AAR Leader can see and display exactly what that entity sees. This includes the effects of head turning and posture changes.
- Fly Mode – The AAR Leader can "fly" through the database using the mouse for control.

During the course of a replay the trainees will be able to see the mission from a number of perspectives. The top down, 2D, and fly views, views that are never available to them during the mission exercise, promote seeing the big picture and learning to see the battlefield. The entity view, seeing through the eyes of others, supports a number of training functions. Did the leaders see an action or problem but fail to respond, or were they not looking in the right direction at all? Do squad members maintain 360° security and report promptly? What was the view from likely and actual enemy positions? The DIVAARS replay provides unequivocal answers to those questions.

Movement Tracks. Movement tracks show, in a single view, the path an entity travelled during an exercise. Markers are displayed at fixed time intervals. Every fifth marker is a different shape than the four preceding it. The display of these markers can be turned on and off. The movement tracks provide a clear display of the path and speed of movement of each member of the unit. In addition, they provide indications of the unit formations and of the location and duration of halts in movement. Thus, the AAR Leader may elect to skip or fast-forward through portions of the replay, knowing that the movement traces for those skipped segments will be observable when the replay is resumed.

Entity Identifier. Because friendly force avatars in the DIVAARS and in the virtual simulators are not always easy to distinguish from one another, a unique identifier is shown above the avatar of each unit member. For example, 2SL is the identifier for the squad leader, second squad. The entity identifiers change size to be readable across all levels of zooming.

Digital Recording and Playback of Audio Program. Audio communications within a unit are important scenario events. DIVAARS records and plays back audio content for all scenarios. This system was developed and tested with an ASTi Digital Audio Communications System (DACS: Advanced Simulation Technology, Inc., 2001). The ASTi system converts all voice communications from live participants to digital messages and outputs them on a Distributed Interactive Simulation (DIS) network using Transmitter/Signal/Receiver Protocol Data Units (PDUs). In addition, DIVAARS records environmental audio information (for example gunshots) from the simulator via the DIS Fire and Detonation PDUs. The DIS timestamps are used to play back the audio at the correct moment during the AAR replay.

Viewing Floors Within a Building. The AAR Leader must be able to follow the action in MOUT scenarios even when a unit enters a building. The AAR Leader can select a building and then select a floor of that building to be displayed. Using this feature, the operator can view and display the avatars going through a building without the problem of walls and upper floors blocking the view.

Bullet Lines. This feature helps to determine what objects are being shot at by each entity, and to identify patterns of unit fire. Bullet flight lines are shown for all weapon firings. The line traces a shot's origin and destination. It is the same color as the originating entity. These bullet lines gradually fade away.

Event Data Collection and Display. DIVAARS has the capability to track many events including shots fired, kills by entities, movement, and posture changes. These data can be shown in a tabular format or graphical display. The AAR Leader can use them as needed to make various teaching points. They can also be used to support subsequent data analysis for research and development applications. Custom events defined by the operator are automatically flagged and can be jumped to during playback. Ten different tables and graphs are available:

- Shots fired, by entity and unit;
- Kills, by entity and unit;
- Killer-Victim table that shows who killed whom, with the option to show the angle of the killing shot (front, flank, or back) or the posture of the victim (standing, kneeling, or prone);
- Shots as a function of time, by entity, unit, and weapon;
- Kills as a function of time, by entity, unit, and weapon;
- Kills by distance from killer to victim, by entity, unit, and weapon;
- Rate of movement of each entity, and aggregated at fire team and squad levels;
- Percentage of time friendly units were stationary;
- Percentage of time friendly units were in different postures; and
- Display of user-defined events.

7.1 Evaluation and Utilization

DIVAARS was developed as part of a comprehensive program to develop capabilities for dismounted combatant virtual training. It was evaluated within the context of the exercises conducted as part of the overall research program. In general, DIVAARS has been rated very highly by Soldiers. Table 8-1 contains Soldier ratings of the systems capability to present information. The ratings were collected as DIVAARS was developed and matured. The data represents Soldier's opinions drawn from a number of different projects. After its development trials in 2001 and 2002, DIVAARS has been used as the AAR tool in the Virtual Integrated MOUT Training System testing at Ft. Campbell, KY, in 2004 [10]. It has been used to test wearable computer generated virtual Dismounted Soldier training systems in 2005.

Table 8-1: Ratings of DIVAARS by Soldiers in Dismounted Soldier Simulation Exercises

The AAR system made clear	Ratings	2001	2002	2004	2005
...what happened during a mission	*SA*	*44%*	*82%*	*62%*	*68%*
	A	*56%*	*12%*	*31%*	*32%*
	Total	*100%*	*94%*	*93%*	*100%*
...why things happened the way they did during a mission	*SA*	*44%*	*76%*	*46%*	*62%*
	A	*39%*	*24%*	*35%*	*35%*
	Total	*83%*	*100%*	*81%*	*97%*
...how to do better in accomplishing the mission	*SA*	*28%*	*71%*	*54%*	*69%*
	A	*56%*	*24%*	*38%*	*23%*
	Total	*84%*	*95%*	*92%*	*92%*

***SA = Strongly Agree; A = Agree*

It was recently included in the suite of capabilities making up the US Navy's Virtual Technologies and Environments (VIRTE) program. Within VIRTE it was used to test methods for measuring Situational Awareness in virtual environments. These measures of Situational Awareness may prove to be a highly effective means of tracking the progress of units in providing the intrinsic feedback needed to support unit performance.

8.0 CURRENT AND FUTURE RESEARCH NEEDS

Changes in training environments, operational contexts, and operational systems has driven AAR research resulting in new tools and procedures [17]. Environments, contexts, and systems continue to change, and thus this process of adapting AAR tools and procedures continues. Networked command and control systems and joint, multi-national operations are two of the variables motivating additional AAR research.

Networked command and control systems enable new forms of extrinsic feedback. Software can be used to provide feedback in mid exercise in the form of intelligent tutors [6] or "during action" review aids [1]. These software applications, if used during actual operations, become sources of intrinsic feedback. Unit responses to these forms of feedback become a new source of topics for the AAR, and they also provide their own AAR aids.

The AAR process may need to be tailored to support joint operations, multi-national operations, and distributed training exercises. Joint exercises include participants from a mix of military services and multi-national operations may involve military and civilians representing a mix of nations and/or cultures. For both joint and multi-national AARs, cultural issues may influence the utility of specific design features of the AAR (e.g., is it acceptable for a leader from another service, country or culture to have their mistakes revealed in front of subordinates or outsiders?). In many military training situations where careers and prestige is on the line, it is possible that participants may be more concerned with defending their actions than with learning how to improve their performance in the future. Successful implementation of AARs under these circumstances may require culture changes that allow for open discussion of performance strengths and weaknesses.

9.0 SUMMARY

Realistic battlefield simulations made it possible for the AAR process to replace the critique as the primary method of providing extrinsic feedback after collective training exercises. Realistic simulations provide participants with intrinsic feedback that cues and guides their performance and, to some extent, let them know how well they are performing various tasks. The intrinsic feedback received by individuals depends upon their job, their location in the battlespace, and the quality of the simulation environment. This intrinsic feedback prepares individuals to participate in interactive discussions that can help a unit decide what happened, how it happened, and how to improve performance. A significant part of the extrinsic feedback process is to bring perceived truth regarding exercise events in line with ground truth (e.g., what actually happened), and the sharing of intrinsic feedback enables a view of the situation that is closer to ground truth than is the view of a single individual. In general, less well trained units will have a greater need for extrinsic feedback, because they will have less knowledge about the ground truth situation during exercises to draw upon. In realistic battlefield simulations, a wide variety of participants are able to see, through intrinsic and/or extrinsic feedback, how their actions contributed to the bottom lines of unit performance.

The AAR process makes use of the Socratic method of asking leading and open-ended questions to guide unit discussions. The AAR process can be expedited through the use of aids that use electronic data streams from exercises to document key aspects of performance that are close to the root causes of unit strengths and weaknesses. Designing these aids and implementing their production is a continuing activity.

The AAR process and/or AAR aids have been tailored many times to fit specific instances of the live, virtual, and constructive training environments and to fit changes in unit equipment and missions. This tailoring activity continues to the present.

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